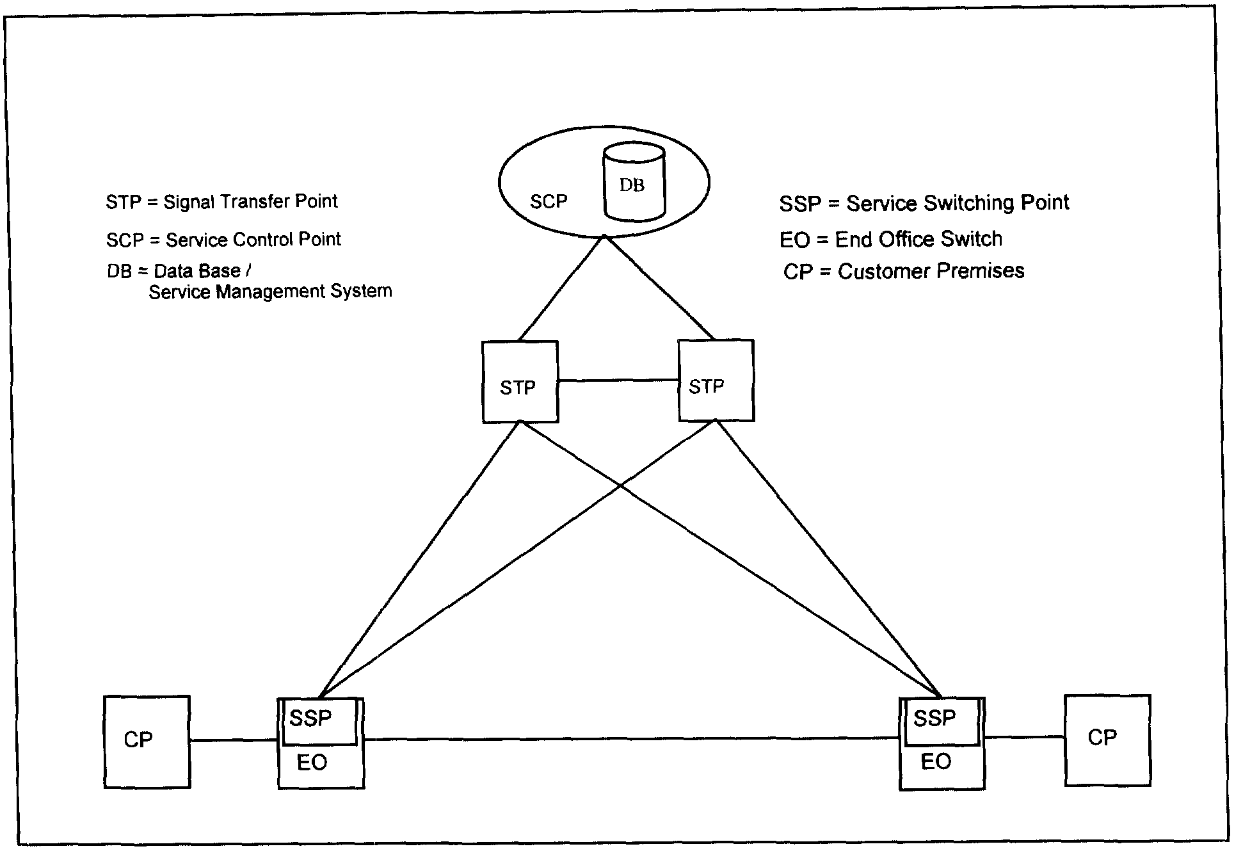

Figure 3 Interoffice Signaling Network Components

3.1.2.4. Interoffice Transmission Facilities

Interoffice transmission facilities carry the trunks that connect end offices to each other and to tandem switches. The signaling links in a Signaling System 7 ("SS7") signaling network are also normally carried over these interoffice facilities.

Interoffice transmission facilities are predominantly optical fiber systems that carry signals in SONET format. Both economic and service quality considerations increasingly prescribe the use of a fiber optic ring configuration to link switches, except for switches that serve few lines or that are too remote from other switches, where ring costs might be prohibitive. In this case, the small switches are typically connected to a nearby wire center housing another end office switch that is on a ring, or the tandem on which the small switch homes, via point-to-point links that are increasingly provided on a route-diverse (that is, redundant) basis for the sake of increasing reliability. Use of rings and redundant point-to-point links in this fashion provides an extremely secure path between any two switches, and the potential for substantial cost savings relative to the ubiquitous deployment of traditional point-to-point facilities interconnecting all switches.

3.1.2.5. Signal Transfer Points

STPs route signaling messages between switching and control entities in a SS7 network. Signaling links connect STPs and Service Switching Points ("SSPs"). STPs are equipped in mated pairs, with at least one pair in each Local Access Transport Area ("LATA").

3.1.2.6. Service Switching Points and Signaling Links

SSPs are SS7-compatible end office or tandem switches. They communicate with each other and with Service Control Points ("SCPs") through signaling links, which are 56 kbps dedicated circuits connecting SSPs with the mated STP pair serving the LATA.

3.1.2.7. Service Control Points

SCPs are databases residing in an SS7 network that contain various types of information, such as IXC identification or routing instructions for 800 numbers in regional 800 databases, or customer line information in Line Information Databases ("LIDB").

4. HM 5.0a Model Organization, Structure and Logic

4.1. Overview of HM 5.0a Organization

Figure 4 shows the relationships among the various modules contained within HM 5.0a. An overview of each component of the Model follows.

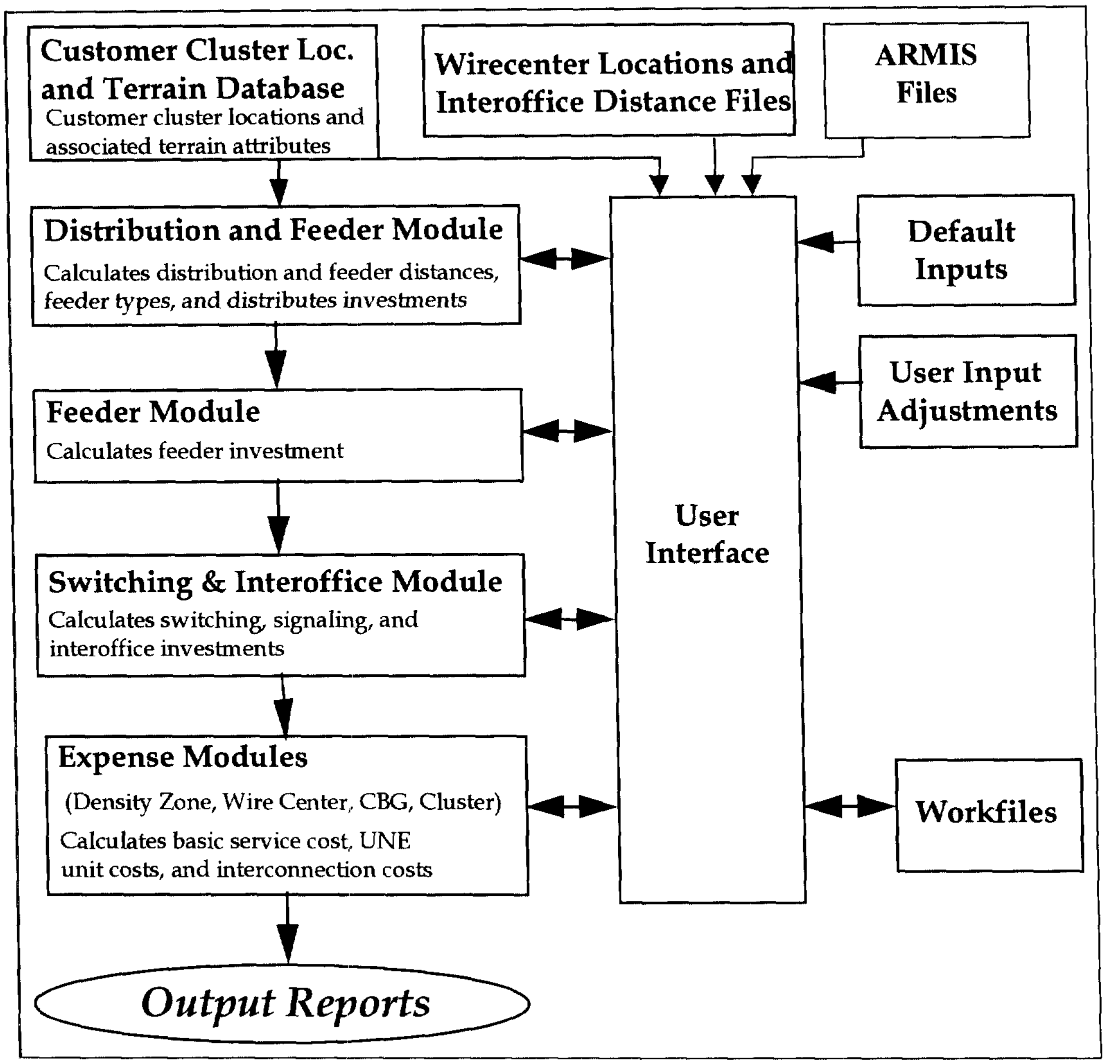

Figure 4 HM 5.0a Organization Flow Chart

4.2. Input Data

Inputs to HM 5.0a include detailed data describing the following items.

- Demographic, geographic and geological characteristics of the areas served by each telephone company. These data records are specific to individual "clusters" of customer locations (i.e., "main" clusters and their subtending "outlier" clusters). They include information on the number of customer locations and lines receiving telephone service in a cluster, the geometric configuration of the cluster's boundaries, the wire center that serves the cluster and the cluster's location relative to this wire center and to other nearby clusters, and the type of terrain that characterizes the cluster. The character and development of these data are described in greater detail in Section 5.

- Wire center locations, and interoffice distances between end offices, tandems, and STPs used to determine the route miles required for interoffice transmission and signaling facilities. These data are largely developed from Bellcore's LERG and NECA Tariff 4.

- 1996 ARMIS data reported by the Tier 1 LECs. These data provide information about current demand levels that the LEC must serve, and relationships between the LEC's embedded expenses and investments.

- Numerous user-adjustable inputs that allow users to set carrier- or locale-specific parameters, and perform sensitivity analyses. These inputs have preset default values based on the engineering experience and judgment of HAI personnel, as well as the judgements of independent subject matter expert consultants to HAI.

4.3. Workfiles

A run "workfile" is created from the input data files when a particular state/company (i.e., study area) combination is run for the first time. As a complete run of the HM 5.0a progresses, intermediate outputs from the HM 5.0a's constituent modules are stored in the run's workfile. Once the run is complete, its workfile may be examined. A great deal of information above and beyond that presented in the Expense Module spreadsheets (that contain the principal final results of the model's analysis) may be obtained from the run's workfile. One example is average loop length, by cluster and by wire center. Additionally, the user may perform separate analyses on the LEC study area by directing the model to create a new workfile for a subsequent run.

4.4. User Interface

The HAI Model includes a user interface program that facilitates model operation, including extraction of data from the input files, providing dialog boxes for users to manipulate model inputs, executing the Excel workbooks that constitute the model, saving intermediate results, and managing the flow of intermediate results between different modules.

The user interface program also performs certain simple aggregation and summarization calculations in Visual Basic for Applications ("VBA"). This shortens greatly execution times and allows users examining the model's Excel workbooks to focus on the model's fundamental engineering logic.[16]

4.5. Distribution Module

The Distribution Module addresses the portion of the network extending from SAIs to the customers' premises. The module determines the lengths and sizes of distribution cable, the associated structures (poles, trenching, and conduit), the number of terminals, splices, drops, and NIDs required to provide service to the specified numbers and types of customers, and the number and type of SAIs and DLC terminals required. The module also calculates certain distances required by the Feeder Module, and, according to those calculations, determines whether to serve a given distribution area using feeder transmission facilities consisting of copper wire pairs, or using DLC running over optical fiber cable. The model selects fiber feeder if any of following five criteria are met:

a) the feeder distance exceeds a user-adjustable crossover distance (set to a default value of 9,000 feet) that limits maximum distance of any copper feeder run;

b) the total copper loop length, including feeder and distribution cable, for customer locations within a main cluster, exceeds a user-adjustable maximum analog copper distance whose default value is 18,000 feet;[17]

c) the main cluster has at least one outlier cluster subtending it;

d) an analysis of the life-cycle costs of fiber vs. copper feeder shows that fiber feeder is the more economical choice, or

e) the "wireless" investment cap is invoked.

These criteria are described in greater detail in Section 6.3.5. If, based on these criteria, copper feeder is chosen, it extends out to an SAI located at the centroid of the main cluster. Copper distribution cable then extends from the SAI to all customer premises in the cluster. If fiber feeder is chosen, it extends from the wire center out to the centroid of the main cluster. From this point, one of two configurations is used to serve the customer locations within the main cluster. If the distance to the farthest customer location in the

[16] Model versions prior to HM 3.0 used Microsoft Excel's Pivot Table feature to summarize various results at the wire center and density zone levels. Although this feature was quite flexible, applying pivot tables to the very large arrays of data required by the model led to very slow execution times.

[17] The analog copper distance refers to the distance over which signals are transmitted in analog voiceband form on copper cable.

main cluster is less than the user-adjustable maximum analog copper distance, a single DLC RT is located at the cluster centroid, and copper distribution cable extends from this DLC RT to all customer premises in the main cluster. If the distance to the farthest location in the main cluster exceeds the maximum analog copper distance, then fiber connecting cable extends vertically and/or horizontally from the centroid to two or more DLC RTs, each of which serves a portion of the main cluster and is located to ensure the longest remaining distance is less than the maximum analog copper distance. From these multiple DLC RTs, copper distribution cables extend to the customer premises in the portion of the main cluster they are responsible for serving.[18]

The HM 5.0a Distribution Module serves outlier clusters that subtend main clusters with analog copper cable if their distance from the DLC RT in the main cluster does not exceed the user-adjustable maximum analog copper distance parameter, and if this outlier cluster has no other outlier clusters either subtending it, or lying between it and the main cluster.[19] If the distance to the farthest subscriber within an outlier cluster would exceed this threshold, the Distribution Module serves the outlier cluster with digital loop carrier equipment using copper-based T1 digital transmission.[20] Once the outlier cluster has been reached, analog copper distribution cables are used to serve the customers located in the outlier cluster.

After the module has determined the quantities of all distribution elements, it calculates the investment associated with these elements, including distribution and drop cable, structures, NIDs, terminals and splices, SAIs, and DLC terminals, using as inputs the user-adjustable unit prices of each element. The numbers and types of elements engineered can be examined in the intermediate outputs of the Distribution Module as recorded in the workfile.

4.6. Feeder Module

The Feeder Module configures the portion of the network that extends from the wire center to the SAIs. Based on information it receives from the Distribution Module, it determines the size and type of cables required to reach the SAIs located in each serving area, along with supporting structures (poles, trenching, conduit, manholes, and fiber optics pullboxes). The Feeder Module then calculates the investment associated with these elements, using as inputs the unit prices of each such element. It passes these investments to the Expense Modules. The numbers and types of network elements required can be examined in the intermediate outputs of the Feeder Module as recorded in the workfile.

[18] If, however, the model invokes a wireless local distribution system, fiber feeder extends to the radio base station located in main cluster, and final distribution is made to customers in outlier clusters over-the-air.

[19] Such an outlier cluster is termed a "first order" outlier.

[20] This technology does not require the use of loading coils or coarse-gauge cable, and it also permits basic rate ISDN and other advanced narrowband services to be provided to all subscriber locations in the model.

4.7. Switching and Interoffice Module

The Switching and Interoffice Module computes investments for end office switching, tandem switching, signaling, and interoffice transmission facilities. In HM 5.0a the user can designate specific wire center locations that house host, remote, and stand-alone switches, respectively, as well as specify inputs for the per-line investments associated with each type of switch. HM 5.0a will then calculate switching investments taking into account the switch arrangements that the user designates.

The switching module determines the required line, traffic, and call processing capacity of switches based on line totals by customer type across all serving areas belonging to the wire center, and based on ARMIS-derived traffic and calling volume inputs. It also determines the required capacity and distances of interoffice transmission facilities, using the traffic data and the interoffice distances that are input to the Module. In doing so, it uses wire center locations and interoffice distances to determine an efficient mix of interoffice SONET fiber rings and redundant point-to-point fiber links. Rings are separately provided for linking host switches to their subtending remotes, and for linking host switches to each other, to stand-alone switches and to the tandem switches on which they home.[21] The numbers and types of elements involved can be examined in the intermediate outputs of the Switching and Interoffice Module as recorded in the workfile.

4.8. Expense Modules

There are four different versions of the HM 5.0a's Expense Module – one for each of the four levels of granularity at which the user can elect to have cost results displayed: by line density range (which also displays total study area costs), by wire center, by CBG, or by customer cluster.[22] Each version calculates the monthly costs for unbundled network elements, universal service, and carrier access and network interconnection. These costs include both the capital carrying costs associated with the investments, and the costs of operating the network. Capital carrying costs include depreciation, return on the debt and equity investment required to build the network, and income taxes on equity return. Network-related expenses include maintenance and network operations. Non-network related expenses include customer operations expenses, general support expenses, other taxes and variable overhead expenses.

Several sources provide information to the Expense Modules. The Distribution, Feeder, and Switching and Interoffice Modules provide network investments by specific plant

[21] At the user's option, small standalone wire centers serving fewer lines than a user-adjustable threshold (default value: one line) may be excluded from being placed on rings, and instead linked directly to its serving tandem using point-to-point links. In this case, the model attempts to physically route these point-to-point circuits through a nearby large wire center, and then over the fiber rings it has otherwise engineered for interconnecting larger offices and tandems.

[22] Although the HM 5.0a engineers no plant based on CBG granularity, the results of its engineering to individual clusters may be rolled up to display cost results at the CBG level. The association between clusters and CBGs is made based on the relative number of lines each cluster contributes to a CBG's total.

category. ARMIS and other sources are used to derive information on network operating and maintenance expense relationships.

The Expense Modules produce reports (either by density zone, wire center, CBG, or cluster) showing the key outputs of the model, including the costs of providing universal service, unbundled network elements, interconnection and IXC access. Further detail about network investments and costs is available from the workfile associated with a model run.

5. Input Data

To accommodate HM 5.0a's evolution to modeling local telephone networks based on actual clusters of customer locations, the input data used in HM 5.0a are much more granular than the CBG input data used in HM 4.0 and earlier. Flowcharts describing the development processes used to prepare these input data for HM 5.0a are attached as Appendix C to this document.

5.1. Line Type Counts by Study Area

Counts of access lines by type (i.e., residence, single line business, multiline business, public telephone and special access lines) for each distinct NECA Study Area for calendar year 1996 are developed from several data sources. These include:

ARMIS 43-08: 1996 data, released 10/01/97;
ARMIS 43-01: 1996 data, released 10/01/97;
NECA USF Loops filing: 1996 data;
USTA report: 1995 data;
RUS report: 1995 data;
USF Data Request: 1993 data;
ARMIS-based line factors.

The rules by which the best of these data are selected are as follows.

a) When NECA Study Area name matches exactly ARMIS Company name, populate line types directly from ARMIS data for business lines (43-08), single line business lines (43-01), residence lines (43-08), special access lines (43-08), and public lines (43-08) data.

b) For remaining ARMIS Companies, determine counts of line types for NECA Study Area name by applying ARMIS line type distributions to total reported NECA USF Loops.

c) For non-ARMIS Companies, match NECA Study Area name to best available data source (i.e., USTA, RUS or USF Data Request) for residence and business line splits.

d) When no company-specific line type data exist, apply average ARMIS line type distributions to reported NECA USF Loops for NECA Study Area name.

5.2. Wire Center List

The source of the wire center information used in PNR's National Access Line Model is Bellcore's LERG database, dated August 1, 1997.[23] The portions of these LERG data that are used in the HAI model are an extract of key data from the LERG called the Special LERG Extract Data ("SLED") – which has been licensed from Bellcore by the HAI model developers.

Certain switching entities (wire centers) in the SLED with Common Language Location Identifier ("CLLI™") codes not marked as end offices, hosts or remotes are then removed from this wire center database. In addition, switching entities that are inactive, or owned by wireless, long distance or competitive access providers are removed as well.

In a few instances, the SLED assigns wire centers to multiple local carriers. This may result from switch collocation. Because the HAI Model requires wire center entries to be unique, such wire centers are assigned to the local carrier having the greatest number of active NPA-NXX codes. If active NPA-NXX codes are equal among companies, assignment is to the carrier having the greatest number of residential lines.

Multiple occurrences of 8-character CLLIs may also occur in the SLED due to placements of several switches at a single wire center location. Because the HAI Model itself engineers multiple switches in a wire center if demand requires it, duplicate occurrences of 8-character CLLIs are removed from the model's wire center list.

5.3. Customer Counts by Census Block and Wire Center

Customer locations must be associated both with CBs, as well as their serving wire center ("WC"). The PNR National Access Line Model, Version 2.0 ("NALM") performs both of these tasks. The PNR NALM uses PNR survey information, Bellcore's LERG, BLR wire center boundaries, Dun & Bradstreet's ("D&B") business database, Metromail's household database, Claritas' 1996 demographic database, and U.S. Census estimates to calculate both the number of residential and business locations and access lines in each CB, and in each wire center in the United States. This summary describes the methodology, data and assumptions used in developing these location and line estimates in the NALM.

5.3.1. Residence Counts

Residential customer location counts are developed by applying the following process.

a) The Metromail household database (described in section 5.4.1, below) is geocoded to the "point" level.[24] In addition to recording the precise six-decimal place latitude and longitude of this household, the CB associated with its location

[23] These LERG data are augmented by data from NECA Tariff 4.

[24] As described in more detail in Section 5.4.3, below, geocoding to the "point" level means that the geocoding software has both found the housing unit's address in its location files and determined a latitude and longitude for the location down to six decimal places of a degree.

is recorded as well. Duplicate household information is identified and eliminated. If two records appear with an identical latitude, longitude and phone number, one of the two records is eliminated.

b) Implied residential household counts are evaluated by comparing Metromail counts to Claritas' 1996 CBG-level projections of households with telephones. When Metromail households exceed Claritas households, Metromail households are used. When Claritas households exceed Metromail households, Claritas households are used, and the total differences are distributed to the constituent CBs in proportion to 1990 U.S. Census household distributions.

c) Access line counts are determined from household counts using probabilities, that is, how likely is it that a household will have a first or second telephone line installed? First line probabilities are provided by Claritas based on demographic age and income profiles by CBG. Second line probabilities are based on a logistic regression using similar demographic information and developed by PNR using its ReQuest™ III residential survey. Multiplicative probability factors are applied to the household counts defined above to derive residential line counts.

d) The above derived residential line counts by CB are then normalized to sum to Study Area wide data on total residential line counts developed in Section 5.1, above.[25]

e) This lines normalization factor is applied to the residential customer location counts in each CB, as well.

The implications of the forgoing process are as follows. Because the primary source of residential location counts is Metromail – which includes all residences that receive direct mail regardless of whether they have telephones or not – the universe of "populated" CBs that the data process captures may include CBs where telephone service is not currently offered or accepted. Thus, the "breadth" of the telephone network that these data will instruct the HM 5.0a to construct is likely greater than the embedded networks of the ILECs. However, because the counts of lines and locations in each CB are normalized to sum to given Study Area wide totals, the "depth" of the constructed network will be consistent with current levels of actual telephone demand.[26]

5.3.2. *Business Counts*

[25] If comprehensive LEC data on residential line counts by individual wire center are available, normalization can be done at the individual wire center level.

[26] In addition, note that these primary source residential location counts derive from precisely geocoded 1997 Metromail data. Thus, these data provide 1997 information on location counts at the CB level. As a result, the model's reliance on noncurrent or nonCB-specific location data (e.g., Claritas 1996 CBG-level projections, 1990 U.S. Census CB counts, or 1995 U.S. Census Update county-level projections) is limited to those locations that show up in such counts that are in excess of the Metromail counts.

Business location counts are developed by applying the following process.

a) The D&B national business database (described in Section 5.4.2, below) is geocoded to the "point" level. In addition to recording the precise six-decimal place latitude and longitude of this business, the CB associated with its location is recorded as well.

b) From the D&B national database, the total number of business lines, as well the probabilities of these lines being single line business lines and multiline business lines such as Centrex and PBX lines are developed. This model is based on an 800,000 firm sample.

c) Because the D&B national business database contains records for only about 11 million out an estimated total of 12 million U.S. businesses, and because the businesses that it misses are almost certainly small businesses, an additional 1 million nonD&B business locations are added to CB counts in proportion to D&B businesses located in the CB. The lines associated with these added business locations are projected by PNR based on an assumption that they employ, on average, between 1 and 4 employees, each.[27]

d) The above derived business line counts by CB are then normalized to sum to Study Area wide data on total business line counts developed in section 2.1, above.[28]

5.3.3. Location and Line Counts by Wire Center

HM 5.0a uses WC boundaries provided by BLR as its primary source to define wire center service areas. These boundaries conform to CB boundaries, and customer locations contained within all of the CBs associated with a WC are then assumed to be served by that WC. Telephone number information (NPA-NXX) continues to be used for backup and data scrubbing purposes when anomalies arise in the BLR geographical assignment process – as can occur if one wire center's boundaries fall completely within another wire center's boundaries.

5.4. Customer Location

The customer location approach used in HM 5.0a is fundamentally different from that of HM 4.0 – or any other approach that uses arbitrary geographic delineators such as CBs, CBGs or latitude and longitude grid cells. Because HM 5.0a's approach identifies the actual locations (accurate to within 50 feet) of most telephone customers, it produces the

[27] To the extent that the D&B database contains firms that are not locatable to the CB-level, these firms are assumed to be distributed across CBs in proportion to located firms within D&B. Their line counts are calculated based on the company characteristics (e.g., employees, SIC) that they report to D&B.

[28] Again, if comprehensive LEC data on business line counts by individual wire center are available, normalization can be done at the individual wire center level.

most sophisticated demographic data set of its type. The process first develops a database of about 109 million customer address records. These addresses are then geocoded (assigned latitude and longitude coordinates). These locations are then divided among wire center serving areas based on geocoded customer location and the BLR wire center boundaries.

5.4.1. Residence Location Data

Data for residence locations are provided by Metromail, Inc. The Metromail National Consumer Database© ("NCDB") is a large, nationally compiled file of U.S. household-level consumer information that includes both deliverable postal addresses (and telephone numbers, when available). The file consists of close to 100 million records – which constitute over 90% of all residential housing locations that the U.S. Bureau of the Census reported for 1995.[29]

To ensure that the data captured are the most current available, this file is updated 65 times per year, and undergoes numerous "hygiene" measures to ensure its continued high quality for direct marketing purposes. Such purposes require the data to reflect postal address standardization practices, incorporate National Change of Address ("NCOA") processing, and permit postal geocoding to street address, ZIP+4 or Carrier Route levels.

The file is compiled primarily from telephone white pages directory data, but also utilizes many other primary sources of information, such as household mover records, voter registration data, motor vehicle registration information, mail-order respondent records, realty data, and home sales and mortgage transaction information, to build a large repository of verified household-level data.

5.4.2. Business Location Data

Dun & Bradstreet collects information on more than 11 million business establishments nationwide. Information is gathered from numerous sources such as business principals, public records, industry trade tapes, associations, directories, government records, news sources, trade organizations, and financial institutions. This information is validated each night. Additionally, D&B conducts millions of annual management interviews to help improve the timeliness and accuracy of its information.

The information is organized by D-U-N-S number, a nine digit identification sequence which allows for the placement of companies within larger business entities according to corporate structures and financial relationships. A D&B family tree may be used to relate separate operating companies to each other, and to their ultimate parent company. D&B also provides "demographic" information on each of the firms in its database. Such information includes counts of employees and the SIC code of the establishment.

[29] This number is also very close to the 101 million households that the FCC finds in 1996, and exceeds the 95 million households that the FCC reports had telephones in that year. See, *Trends in Telephone Service*, FCC Common Carrier Bureau, Industry Analysis Division, March 1997, Table 1.

5.4.3. Geocoding

Geocoding is used in order to most accurately assign known customer locations to actual, physical locations. Geocoding is also known as location coding. It involves the assignment of latitude and longitude coordinates to actual street addresses. Geocoding software is sophisticated enough to provide information regarding the source and precision of the lat/long coordinates selected. This precision indicator allows PNR to select only those addresses that have been geocoded to a highly precise point location. Geocoding also allows customer location points to be assigned less granularly to the CBG level, or higher. Almost uniformly, geographical address locations are derived from enhanced versions of the USGS' TIGER database.

To perform its geocoding, PNR uses a program by Qualitative Marketing Software called Centrus™ Desktop. The enhanced data behind Centrus is provided by GDT. Premium GDT data are updated bi-monthly to ensure accuracy. These data integrate new information from US Postal Service ("USPS") databases and private sources so that new streets and additions and changes to ZIP codes, street names, and address ranges are included as soon as possible.

Centrus™ Desktop allows geocoding on two levels. The first is a match to the actual address -- which is the only type of geocoding used in HM 5.0a customer location. The second is a match to a ZIP code (ZIP, ZIP+4, ZIP+2) level. Because of the lesser accuracy in the second method, these geocodes are not used in PNR's process of assigning customer locations.

Within the geocode process, there are a number of options available to the user. Each of these options determine the quality of the matches allowed in the end-use geocode. For purposes of customer location, addresses are always matched to the "Close" setting. "Close" allows for minor misspellings in addition to incorrect or missing directionals (North, East, etc.) or street types (street, road, etc.). Although ZIP-based geocodes are generally accurate enough for most applications, they are not considered good enough for actual customer locations and are not used to develop and locate customer clusters in HM 5.0a.

Data hierarchy in address geocoding starts with the State. The hierarchy continues with City, Street Name, Street Block, and finally, House Range. Typically, a Street Block is the same as an actual physical block but it can also represent a partial block as well. The House Range displays address information from the USPS. Additionally, where there are gaps in the actual address range, the House range will account for these gaps.

Initially, the address coding module in Centrus™ Desktop compares the street addresses from the input file to the records contained in the USPS ZIP+4 directory and the enhanced street network files. If the address is located in the USPS files, the address is standardized and a ZIP+4 is also returned. If this address is also found in the street network files, Centrus™ Desktop determines a latitude and longitude for the location.

Optionally, if the address is not found in the street network files, location information may be applied from the ZIP level.[30]

Location codes generated by Centrus™ Desktop indicate the accuracy of the geocode. For purposes of customer location clustering in the HM 5.0a only those geocodes assigned at the 6-decimal place point location made directly to the street segment are used.[31]

While the software and data used allow for a much more comprehensive output of data elements, for use in HM 5.0a customer location, the following addressing elements are extracted:

Address
City
State
ZIP
ZIP+4
Latitude
Longitude
Census Block
Match Code
Location Code

5.4.4. Gross-up

The above-derived precisely geocoded locations are then counted by CB. These geocoded location counts by CB are then compared to target total line counts for that CB derived by the PNR NALM (as described in section 2.3, above). If the geocoded location counts are less than the target count, the residual number of customer location points is then computed, and geographical locations for these points are generated. This process is performed by PNR using TIGER file CB boundaries. Each of the additional number of customer location points that a CB requires to total to its target count is generated and assigned a geocode so as to place these "surrogate" points uniformly along the CB's boundary. While these boundary-assumed locations for the gross-up or surrogate points are plausible – because most CBs are bounded by roads – this is also a conservative placement of the gross-up points because it assumes they are maximally separated from one another.

[30] Note that ZIP+4 codes may be very precise. In general, they are specific to the face of single city block. While it may turn out that accuracy to the street block face is quite sufficient for accurate cost modeling of local telephone networks, in the interest of conservatism, these type of geocodes are not presently used in HM 5.0a data.

[31] Furthermore, placement of the address along the street segment is quite precise. The Centrus geocoding software and reference data also make use of USPS determinations of whether the segment contains a continuous or discontinuous range of address numbers. Thus, if the addresses on a block face run from 200 to 250 and 274 to 298 (with the range between 252 and 272 missing), an address of 250 will be geocoded, it will not simple be geocoded as at midblock.

the serving area. The line density is defined as the total number of subscriber access lines per square mile. While entire serving areas are associated with a given density zone for purposes of accumulating density zone results, HM 5.0a makes a separate density zone determination for the main cluster and the outlier clusters, based on the CBG to which each belongs, when it is selecting which density-zone-dependent factors to use in a calculation. In HM 5.0a, as in HM 4.0, line density is broken down into nine different density ranges.

Density Ranges (lines/sq. mile)
0 - 5
5 - 100
100 - 200
200 - 650
650 - 850
850 - 2550
2550 - 5000
5000 – 10,000
10,000 +

6.2.5. Economic Adjustment of Structure Fractions

The HM 5.0a Distribution and Feeder modules automatically adjust buried and aerial structure fractions to account for the plant placement costs occasioned by local soil and bedrock conditions. The user specifies nominal buried and aerial fractions, along with an "at risk" portion of the buried cable fraction that unfavorable cost conditions can cause to be shifted to aerial. The model calculates the local relative costs of buried and aerial structure -- including both the additional placement costs arising from local terrain conditions as well as the life-cycle maintenance and capital carrying costs of the different structure types.[45] This local relative life-cycle cost of buried versus aerial structure is then ratioed to the national norm for relative buried to aerial life-cycle cost. The model then adjusts the aerial fraction up or down (and buried fraction in inverse fashion) from

[45] This calculation of the relative life-cycle costs of plant placed on various different structures is computed as follows. First, per-foot materials' investment costs are calculated, and added to the per-foot investment cost of the particular structure type – adjusted for the assumed amounts of inter-utility structure sharing that apply to the particular structure type. Second, annual charge factors are developed for capital carrying costs and maintenance costs. These factors are developed within the "LCFactors" and "CCCFactor" sheets of the Distribution Module using the same methodologies described in Sections 6.6.2 (for capital carrying costs) and 6.6.3.1 (for network maintenance costs) documenting the HM 5.0 Expense Modules. Finally, the plant net investment cost is multiplied by the sum of the annual capital carrying cost and maintenance cost factors, to yield the relevant annual life-cycle per-foot cost of the particular type of plant.

its national default value by up to the full amount of "at risk" structure, depending on the degree of difference in local versus national norm life-cycle costs.

A logistic curve is used to specify the sensitivity of structure choice to differences in relative cost. The "s-curve" shape of the logistic function suggests that initial divergences of local relative structure costs from "normal" relative structure costs cause more structure to be shifted across types than do further increases in this divergence. The user-adjustable default fraction of buried structure that is "at risk" to be converted to aerial structure based on adverse local life-cycle costs is 75 percent.

6.3. Distribution Module

6.3.1. Treatment of Main Clusters

HM 5.0a lays distribution plant directly over the rectangular areas where customer clusters are located. This plant extends from the SAI location (or locations) to the customer premises in the cluster. The basic distribution configuration employed by HM 5.0a for the main clusters is a "grid" topology, in which tapering backbone cables run north and south from the SAI(s), while branch cables extend east and west from the backbone cables past the individual subscriber locations.[46] The backbone cables terminate one lot depth inside the north and south boundaries of the rectangle. The branch cables run to within one lot width of the east and west sides of the rectangle.

The Module performs a test to ensure that the longest combined backbone and distribution cable run does not exceed a user-adjustable maximum copper distance whose default value is 18,000 feet. If the maximum distance would otherwise be exceeded, the model will extend fiber subfeeder "connecting cables" from the centroid of the cluster to two or more DLC RTs (and adjacent SAIs) positioned to ensure the maximum distance is not exceeded. The number of RT/SAI locations is determined by separately checking that the backbone and branch cable lengths do not exceed a fraction of the maximum distance calculated from the aspect ratio of the cluster shape, and splitting the cluster area in either or both dimensions to create the necessary two or more subareas.

Main clusters with total areas less than 0.03 square miles and line densities greater than 30,000 lines per square mile are identified as consisting of high-rise buildings, and accorded special treatment appropriate for high rises.

This high-rise test identifies cases in which a serving area is very small, but its line density is so high as to be incompatible with any explanation other than vertical "stacking" of the customer locations. In such cases, the model assumes the distribution cable required to serve the main cluster consists of riser cable inside the high rise building, and that the SAI required for service is located in the basement of such a building. The number of floors in the high rise buildings is estimated by dividing the

[46] The coordinate system used in the HM 5.0a to denote "north," "south," "east" and "west" is the Vertical and Horizontal (V & H) system that is standard in the telephone industry. These coordinates are internally consistent, but differ slightly from "true" north, south, east or west.

occupied building space by the area of the main cluster, reduced to account for streets and sidewalks.[47] The occupied building space in square feet is calculated as follows:

occupied space = 1,500 * # households + 200 * # employees.

For "regular" serving areas that do not meet the high-rise test, the model computes the plot size per customer location by dividing the effective area of the main cluster by the number of customer locations in the main cluster, as stated above. The model assumes that each customer plot is twice as deep as its frontage.

However, a refinement to this calculation is required to account for the fact that many households occupy dwelling units that cannot be characterized as single family detached homes. Likewise, structures occupied by business establishments may range from small single-tenant stores on small lots to large, multi-floor buildings (high-rise buildings are treated separately). A residence and a business methodology are adopted to represent more realistically the actual situations that may occur.

For residences, the Census database supplied by PNR identifies the number of households located in various types of buildings. HM 5.0a assumes that the space occupied by residences other than single-family detached units is half that of detached homes, and accordingly reduces the number of customer locations in calculating the effective plot size of detached homes. This reduction represents more adequately the space (including the actual living quarters, shared facilities, parking lots, and other area around buildings) that households in multi-dwelling units occupy relative to a detached single-family home. The reduction in effective customer locations is made before calculating the lot size in the manner described above. The intent is to calculate the effective lot size that detached homes would have in the main cluster, and lay out the distribution cables accordingly. The model assumes the grid pattern of cables continues throughout the areas where multi-tenant units are located; thus, there is no additional efficiency associated with serving such premises.

The assumed reduction in effective households is conservative because the model assumes multi-tenant units displace one-half of a regular-sized lot. Thus, the model will consequently underestimate the effective lot size of detached homes because it is counting too high a number of equivalent customer locations. This underestimate of effective lot size causes more lots to be assumed, and more distribution plant to be placed, than actually is necessary to serve this area.

6.3.2. Treatment of Outlier Clusters

Outlier clusters, each consisting of one or more customer locations, are served in HM 5.0a by the nearest main cluster. A main cluster and its subtending outlier clusters together constitute a serving area.

[47] The reduction in main cluster area for urban streets and sidewalks, expressed as a fraction; is user-adjustable with a default value of 0.2.

Outliers are connected to the main cluster by copper road cables extending from the centroid of the main cluster to the centroid of the outlier. A given outlier may be directly connected to the main cluster, in which case it is labeled a "first order" outlier, or it may be connected to another outlier which in turn is connected directly to the main cluster or another outlier. Such connections are depicted in Figure 5. Outliers that are not directly connected to the main cluster are considered to be "higher order" outliers.

Fiber feeder is extended to any main cluster that has at least one outlier cluster. The road cables to the first order outliers extend from the point at which the fiber feeder terminates in the main cluster. If the right-angle route distance from the main cluster to the farthest customer location in a first order outlier is less than a user-adjustable distance parameter whose default value is 18,000 feet, the road cable carries an ordinary analog voice signal, and is called "subscriber road cable." If the farthest customer in an outlier is more than the default distance from the main cluster, or the outlier is a higher order outlier, the cable carries a digital T1 format signal to a remote T1 terminal at the centroid of the outlier, and is served by "T1 road cable." From the T1 RT, copper cables carrying analog signals extend the remainder of the way to the customer locations within the outlier.

A T1 road cable contains copper pairs, and supports T1 signals used to provide digital connections between the fiber DLC remote terminals located at the centroid of the main cluster and subsidiary remote T1 terminals located at the centroid of each outlier cluster. The model assumes conventional T1 transmission with a user-adjustable 32 dB repeater spacing.

In HM 5.0a the cables serving subscribers from the remote terminals are assumed to be different than those that carry the T1 signals to the remote terminals. The total investment calculated for the T1 system includes the cost of the T1 interfaces in the main cluster's DLC remote terminal.

6.3.3. Customer Drop Arrangement

No matter whether a customer is located in a main cluster or outlier cluster, the distribution arrangement at the customer's premises is similar. At a point close to the customer's location, a splice and block terminal are installed to connect a drop cable containing several wire pairs from the distribution cable to an aerial or buried drop to the NID located on the wall of the premises.

6.3.4. Investment Cap to Reflect Potential Wireless Technologies

As requested in the FCC's FNPRM, the HM 5.0a permits the specification of a user-adjustable cap on the model's relevant wireline investments to reflect potentially more economical wireless distribution technologies.[48] In the HM 5.0a this cap, if invoked by the user, is implemented by placing a ceiling on the per-line investments computed in the

[48] It is unclear whether such systems exist, whether their costs can be modeled accurately across all demographic and terrain situations, and whether these systems can meet the FCC's criteria for supported universal service.

Distribution module (i.e., NID, drop, terminal and splice, distribution cable and structure, SAI, and DLC RT) that would be replaced by the wireless system.[49]

The optional cap calculation considers the cost of two different wireless systems: a "point-point" system serving customers on a one-one basis, and a "broadcast" system serving a number of customers from a shared base station. The point-point cost is assumed to be a fixed amount per line served; the broadcast system cost is structured as a fixed base station cost serving up to a given maximum number of customers, with the cost of the base station distributed among the number of customers that use it, plus a per-line cost of the radio terminal equipment at each customers' premises. Generally, the broadcast system is more expensive than the point-point system for a few lines in a serving area, but less expensive if the system is loaded to a substantial portion of its maximum capacity. The Model compares the cost of the two wireless systems to each other for a given serving area, then compares the cost of the lower-cost system to the wireline cost. If the most economical wireless system's cost is lower, the Model zeroes out the cost of the wireline distribution components for that serving area, and substitutes the cost of the wireless distribution system, while retaining the feeder portion of the wireline network.

6.3.5. Determination of Feeder Technology

Because it must calculate all of the outside plant distances, to determine the kind of road cable required, the Distribution Module also determines whether copper or fiber feeder and subfeeder are utilized for a given serving area. If fiber feeder and subfeeder are used, these extend from the wire center to the main cluster centroid. The subfeeder terminates at one or more DLC RTs and adjacent SAIs -- located to ensure that the remaining distribution cable lengths do not exceed the user-adjustable maximum analog copper length. In all cases, copper distribution cable is used to link SAIs to customer premises. The decision whether to use fiber feeder depends on whether any of the following conditions are met.

a) The total feeder and subfeeder distance from the wire center to the main cluster centroid is greater than the user-adjustable Copper Feeder Max Distance value, whose default is 9,000 ft.

b) A life-cycle cost analysis of fiber versus copper feeder on the route shows that fiber is more economical.[50]

c) The longest distribution cable run from the wire center to the farthest corner of a main cluster is greater than a user-input maximum analog copper distance, whose default value is 18,000 ft.

[49] It is assumed that the cost of the remote terminal electronics for the fiber feeder facilities serving the wireless radio sites would be included in the wireless system cost.

[50] The life-cycle costs of fiber versus copper feeder are computed using the same methodology, as described earlier, to calculate the life-cycle costs of outside plant placements on different structure types.

d) There is at least one outlier cluster subtending the main cluster.

e) The wireless investment cap is invoked and leads to the conclusion that one of the two wireless systems is the least-cost solution for the serving area.[51].

6.3.6. "Steering" Feeder Routes

In HM 5.0a the user may elect to have the Feeder Module "steer" feeder routes toward the preponderance of main clusters within a quadrant. The model computes an angular offset from the cardinal default values of 0°, 90°, 180° or 270° by weighting each main cluster's angular offset coordinate by its radial distance from the wire center location, and then determining the weighted average angular displacement. When feeder cable is steered in this fashion, the Feeder Module also applies a route-to-airline (R/A) distance multiplier. The value of this multiplier may be specified by the user within an allowed range of R/A values. Subfeeder cables branch perpendicularly off the main feeder route toward main clusters. This branching is perpendicular both when feeder routes go in the cardinal compass point directions, as well as when the feeder is steered at an angular offset from these cardinal directions. Alternatively, the user may elect to "turn off" feeder route steering and have the Module calculate feeder distances using "right angle routing" in the four cardinal compass point directions -- as employed in HM 4.0.

6.3.7. Calculation of Distribution Investments

The model uses the customer location and cluster data, including cluster sizes and locations, number of lines, and lines density; and applies these demographic and architectural considerations to determine the total distribution distances involved. It then estimates the investment in distribution cable, supporting structures, terminals and splices, drops, NIDs, and SAIs.

In calculating these investments, the model requires a number of data elements which are provided to it through adjustable user inputs. These include cable sizing factors, the amount of structure sharing with other utilities, the relative mix of aerial, buried, and underground facilities, the unit material and installation costs of the various network components, the demographic factors identified in Section 6.1 above, and factors relating difficult terrain characteristics that may increase installation costs.

Appendix B defines each user input and the default value(s) for that input as set by the model developers. The set of inputs pertinent to the distribution calculations are inputs B1 through B45 (basic distribution and drop components), B58 through B69 (DLC components), B180 (structure sharing), and B197 through B201 (excavation and restoral activity frequency and costs), in Appendix B.

Three sets of the input parameters bear special attention. The first is the set of cable sizing factors appearing as item B18 in Appendix B. Sizing factors are intended to

[51] When wireless is used, it is assumed that a minimum of four fibers must be used to connect the radio sites to the wire center.

provide reserve capacity above and beyond the lines requirement determined by the model. If, for instance, a given cable segment must serve 75 lines and the sizing factor set by the model is 0.50, then the target cable size determined by the model is 75/0.5, or 150. However, cables are available only in discrete sizes, as shown in Item B9 in Appendix B. The model selects the cable size at or most closely above the minimum size calculated. In this example, this corresponds to a 200 pair cable. Thus, the achieved fill is 75/200, or 0.375. Generally, the average achieved distribution fill is significantly less than is indicated by the raw cable sizing factors shown in Item B18. The Model outputs display this average actually achieved fill both at the SAI and at the MDF.

Second, as discussed earlier, the HAI Model assumes that forward-looking practices of efficient telephone companies and other utilities will involve substantial structure sharing. The default levels of structure sharing assumed in HM 5.0a, stated as the percentage of total structure costs assigned to the telephone company, are shown in Item B180 of Appendix B. In HM 5.0a the amount of structure sharing depends both on the type of structure -- poles and trenching -- and the density zone. HM 5.0a assumes, conservatively, that there is no sharing of conduit in underground installations.

Finally, HM 5.0a offers an optional cap on distribution investment as discussed, above. This cap, enabled by Parameter B41, compares the total per-line wireline distribution costs for all distribution components to the cost of two types of wireless systems. One system's per-line cost is expressed by B42; the other system's cost is parameterized by a base station cost, B43, maximum customers served by a base station, B45, and per-line radio system equipment cost, B44.

6.3.8. Calculation of SAI and DLC Investments

The SAI in each serving area provides an interface between the feeder and distribution facilities. Each SAI consists of a cabinet, including suitable physical mounting, and a simple passive cross connect. In the case of fiber feeder there is an adjacent DLC remote terminal. SAI investment is determined by the number of distribution and feeder pairs required to be served. The model equips multiple SAIs if the pair requirement exceeds the maximum SAI capacity.

Urban areas normally have feeder cable running directly into the basement of large buildings, rather than interfacing at an SAI outside of the building. In such cases, the SAI, located in the building, is significantly less expensive than the outdoor SAI. This type of interface consists of a plywood backboard and inexpensive "punch-down blocks," rather than the heavy steel weatherproof outside terminals found in less urban areas. HM 5.0a thus differentiates between outdoor and indoor SAIs, the former being the normal case, and the latter being used when a serving area is identified as a high-rise building.

The Distribution Module sizes and calculates the investment in the SAIs required in each serving area based on the number of distribution and feeder pairs required to serve both the main and outlier clusters and the urban/non-urban characteristic of the serving area. The pertinent input parameter for the SAI is identified as B38 in Appendix B. It is the installed investment in an SAI, stated as a function of the number of distribution and feeder pairs served by the SAI. The model equips each serving area with one or more SAIs. The number required is determined by comparing the total "in" and "out" lines demand to 7,200, which is the maximum number of pairs that can be supported by a single SAI.

A given serving area may be served by either fiber feeder or copper feeder. When fiber feeder is used, one of two types of DLC equipment is selected. The first is designated "High Density" DLC, and is GR-303 compliant."[52] The second is designated "Low Density" DLC, and is also GR-303 compliant. The choice between these two types is determined for each serving area. If the number of lines is below a threshold value, "low density" DLC is used; above that threshold, "high density" DLC is assumed. The threshold is user-adjustable, with a default value of 480 lines.

The investment in DLC equipment, when it is used, is calculated in the Distribution Module. The parameters involved in this calculation are identified as Items B58 through B69 in Appendix B. For either type of DLC system, low density or high density, the investment is calculated based on user-adjustable amounts for site and powering (B58), for common equipment (B61), and for channel units (B62). Other inputs in the range of B59-B69 specify, for example, the number of fiber strands per RT, the maximum initial lines that can be served by the DLC, the number, size and additional common equipment requirement of additional line increments, and the capacity and cost of plug-in cards for POTS and coin service. The DLCs are equipped by the model with line cards of the type required to provide the appropriate grade of service on the analog and digital (T1) pairs fed off of the DLC – at the distances implied by the structure of the main and outlier clusters.

6.3.9. *Calculation of Drop Investments*

HM 5.0a computes a weighted average drop investment in each density zone on both a per-drop and per-pair basis. The model uses the detailed household type and business line information contained in the demographic database to compute the total drop investment in each serving area. The total drop investment is applied to the sum of all households in single family attached and detached dwellings, mobile homes and "other" dwelling types, all two- and four-household dwellings, and all single-line businesses. The per-pair drop investment applies to the remaining business lines, the adjusted private line total, and public lines, as well as to all households in multi-unit buildings containing five or more households.

6.4. *Feeder Module*

6.4.1. *Overview*

[52] GR-303 (which is also called "TR-303" in earlier documents that are still in common use in the industry) is a Bellcore requirements document dealing with interfacing a DLC system with an end office switch.

The Distribution Module produces as inputs to the Feeder Module the main feeder and subfeeder cable distances for each serving area. The Feeder Module uses these inputs to calculate the investment in feeder plant.

As seen earlier in Figure 1, feeder cable begins at the wire center and ends at the SAI located within each serving area. Figure 6 displays the basic main feeder and subfeeder architecture assumed in the model.[53] A key difference between HM 5.0a, compared to HM 4.0, is that in HM 5.0a the unit of population served by a given feeder and subfeeder cable combination is the main cluster and its subtending outlier clusters, rather than a CBG. Note that since a given main cluster can be surrounded by outlier clusters and/or areas with no population, there may be gaps between the main clusters, as shown in the drawing. In areas of dense population, they are, however, likely to be contiguous.

[53] As discussed previously, subfeeder may be linked at the main cluster centroid to connecting cables that run to two or more DLC RTs located at other points within the main cluster. Such connecting cables are also classified as feeder cable by the model, since telephone companies classify all cable on the wire center side of the DLC RT as feeder cable.

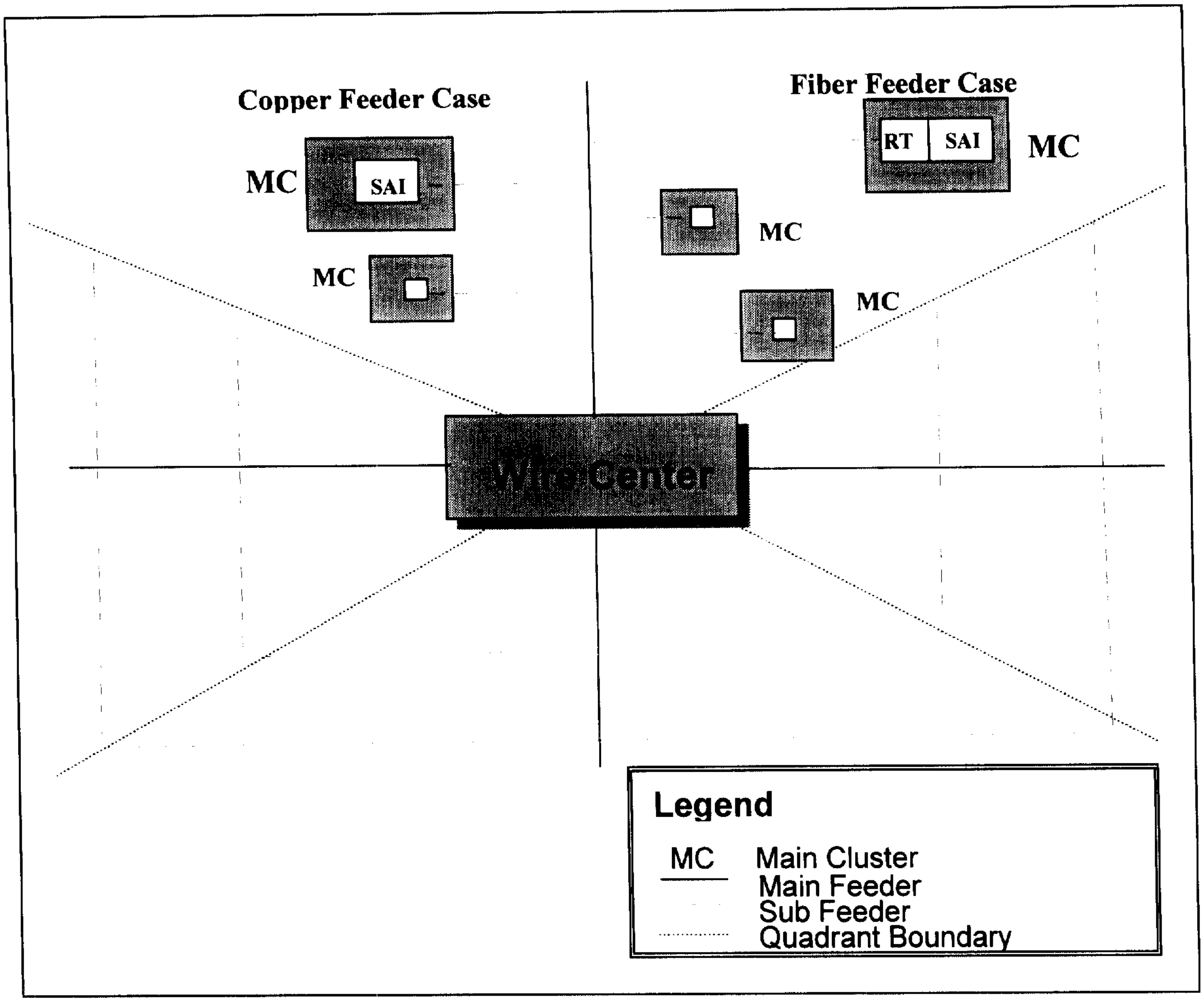

Figure 6 Feeder Architecture

As many as four main feeder routes may terminate at each wire center. Each feeder route serves one quadrant of the wire center's service area, and quadrant boundaries form angles of ±45° with the main feeder routes.[54] Each main cluster is served by the main feeder route associated with the quadrant containing the centroid of the main cluster. To reach each cluster, a subfeeder branches from the main feeder at right angles and extends to an SAI within the cluster. As described in Section 6.3.6 on the Distribution Module, each of the four main feeders may, at the user's option, be "steered" towards the preponderance of main cluster locations within the quadrant in question, and a route-to-air multiplier applied to the "steered" feeder route distance.

The main feeder cable sizes for both fiber and copper facilities are a function of the total number of lines in each serving area, and the feeder sizing factor for those serving areas.

[54] Because HM 5.0a uses V&H coordinates to locate clusters and wire centers, feeder routes are assumed to emanate from the wire center along the V&H axes. These axes are rotated slightly clockwise relative to latitude and longitude axes.